E/CONF.39/A/368
12 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A. 3. 3. 1

Italy

SOME HYDROGEOLOGICAL AND GEOPHYSICAL CRITERIA ADOPTED FOR GROUND-WATER RESEARCH IN THE HIGH NILE RIVER VALLEY AND THE RESULTS THEREOF

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SOME HYDROGEOLOGICAL AND GEOPHYSICAL CRITERIA ADOPTED FOR GROUND WATER RESEARCH IN THE HIGH NILE RIVER VALLEY AND THE RESULTS THEREOF -

No. 2111, 2131
A.3.3.1

by
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1 - Foreword

In the years 1960-61-62, the ITALCONSULT carried out, for the account of the Ministry of Land Reform of the U.A.R., a survey to plan a series of land improvement and irrigation works for the agricultural valorization of some desert districts of High and Miggle Egypt. In the framework of this survey, the authors were able to carry out locally ground water studies and research; the criteria of this research are briefly illustrated in this paper.

In order to frame the problem and particularly the fact that underground waters are not directly supplied from the atmosphere throughout the Egypt territory, it must be stated in advance that all that regards temperature, rainfalls, atmospheric humidity, winds and sunlight hours of the region is typical of mainly arid tropical zones. Therefore, considering tha difficulties concerning the supplying of the aquifer strata the researchers were faced first of all, with the necessity of carrying out a geological and geohydrological survey of lithological formations emerging both inside and outside the land-improvement districts to study.

For the study of relationship among the various hydrogeological units with respect to the Layers ascertained both through surface geological survey and through mechanical drillings, a geophysical research was later carried out. The geological differences in depth, known through geophysics, were especially sought after for the information they might supply with regard to the consistency of the aquifers, the pick up depth of surface or deep waters, and, in some cases, to establish a comparison between the stratigraphic features of the soil of the Nile bed and those of the soil where phreatic water phenomena take place on the banks of the river itself.

Mechanical drillings were carried out, sometimes, with both a geognostic and hydrological aim so that all hydraulic measurements (flow, permeability, phreatimetric) necessary in order to define practically the problem stated with a purpose for the utilization of well water.

2 - Geognostic Research

This research aimed above all to studying the areas where there was an underground water circulation, within the districts that were to be covered. These particular districts are from 5 to 15 kms from the Nile, and begin where the actually cultivated land ends, spreading toward the desert inland (fig. n.1)

From the morphological point of view, in the area which is being studied, broad valley sections (Wadi) are found, having bottom height around 80-90

metres above sea level, and seldom conveying meteoric water. The actual cultivated area in Egypt is few kilometres wide and is generally completely flat. The new districts, instead, are more irregular.

The geological environment, a survey detail of which is shown in fig. 1, is characterized by a series of sedimentary rocks at its surface; this formation 400 or 500 m thick covers the crystalline rocks of the base. Deep geognostic drillings have enchanced the results of surface geological surveys and of geophysical prospections. An accurate paleontological study of the samples extracted has contributed, however, to the knowledge of the region from the geological point of view.

The sedimentary spreads from the alluvial loose deposits of recent wind formations to the Pleistocene terrace alluvions, to the blue-grey Pliocene clays, to the limestone and marly Eocene limestones, down to Cretaceous clay, sandstone, and phosphate beds alternances. Finally, at the base of the sedimentary, there are the well-known Nubian sandstones, generally with no fossils, sometimes glauconite in large subhorizontal banks, with medium and fine grain, subjected to a tectonic vertical fracture.

Moving Northwards along the Nile river valley, at Assuan, the pre-Cambrian crystalline (granites and syenites) plunges beneath the sedimentary, never to reappear North of Assuan. The Nubian sandstone, widely outcropping up to Assuan, disappear near Kom-Ombo, only to appear again in very narrow spots between Idfu and Isna. Coming out of the Nile river valley, especially Westwards, surfacing Nubian sandstone spreads very far North, greatly affecting the New Valley.

On the basis of the datas ascertained through the geognostical surveys and of the permeability characteristics of the formations crossed by the drillings the presence of the two already-mentioned different aquifers stratum are evident. The first concerns the loose gross quaternary deposits with a permeability for porosity, while the second concerns deep Nubian sandstone, there where they appear in powerful banks, interested mainly by a fissure permeability. The ground water being into the quaternary sand and gravels, alongside the Nile's banks and at water level, is separated from the deep artesian aquifer stratum by all the thick series of impermeable Tertiary and superior Cretaceous formations, which extends from the Pliocene clays all the way to the Nubian series, where this shows abundance of impermeable silt strata. This aquifer stratum does not exist where its impermeable bed surface lifts above the Nile's level.

As to permeability characters of the Nubian series, fractures have appeared to be rare and of permeability almost irrelevant for practical purposes as it happened in well WA 5 B, where clays strata prevail, which happens at the basis of the series, water-bearing fractures are more frequent and cause several aquifer strata under pressure, located at various depths, separated from one another by impermeable alternances richer in clay clayers.

On the basis of the hydrogeological elements thus ascertained, it was possible to plan conveniently both the geophysical and the strictly geological hydrogeological research.

3 - Geophysical Prospecting

The main themes with which geophysical research is concerned were

two: a superficial and a deep one.

The first was the traditional determination in water research of the contact between recent superficial formations and Pliocene clays.

The deeper them was more complicated, as it had a double edge; in fact, when searching for deep waters, it is important to determine the so-called Nubian sandstone formation, and therefore also the two contact surfaces the top one with clay formation (Eocene limestones are lacking in the zone) and the lower one with its crystalline bed.

The only system applied in the survey was that of the vertical electrical sounding, as it is easier and less expensive than seismic methods, which, however, might have been successfully employed and would have been, as we shall see, very useful.

Naturally, the small irregularities of the contact between the alluvion and the clay were of great interest, and therefore the superficial survey required a rather sizeable quantity of electrical soundings; the shape studied with much detail.

For this reason, only one third of the electrical soundings has a length spread sufficient to reach at least 500 m deep, while all the others are very shallow.

The possibility of individuating a formation by the electrical method depends, as it is well known, on two essential elements: the ratio between the resistivity of the formation itself and that of the two top and bottom formations, as well as on the ratio of the thickness of the formation and its depth.

We shall now see, on the basis of the conditions that have been exposed, the aspects of research in the area of Isna, in the solution of these two problems.

The first problem is usually worked out very easily; however, in several zones of the Isna territory, and much more in other areas South of it, as Wadi Abbadi and Saida, two remarkable difficulties have been met with.

The more superficial layer of the alluvial formations is composed of very thin sand, absolutely incoherent and naturally dry. Its resistivity is therefore very high for several meters, in the range of 10^3 - 10^4 ohm m. The permeable formation, instead, drenched with water, has a much lower resistivity, of few scores of ohm m; finally, clays have a resistivity of few ohm m. In such conditions, if the thickness of the first is half or less as that of the second formation, the curve practically may be confused with a two layer one and the determination of the middle layer is impossible. The permeable formations imbued with water are confused with the basic clay; electrical research, in such cases, may only give the top of the first layer.

All experts are well aware that crescent and decrescent resistivity successions are those which make interpreting more difficult. In such cases, the process indicated by Dr. Alfano may be useful (+). It consists of the use

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(+) L. Alfano - Geoelectrical prospecting with underground electrodes - Geophysical Prospecting, vol. X-N.3 - 1962

of electrodes placed at a certain depth in the ground.

The contemporary use of electrical profiles and of some seismic profils, limited to the most difficult zones, may diminuish remarkably this hindrance.

The second difficulty which was met is the enormous contact between electrodes and ground, which would often reach several hundred thousands ohm m. It has two negative effects: first of all, the current that one may succeed in conveying into the ground decrease even down to few mA, which is absolutely inadequate soon reach rather low values. The other obstacle consists of the fact that the resistance of the potentiometric circuit grows enormous and even so they are far from easy.

This problem, which seems at first irrelevant and easily surmountable gave very much trouble to the Foundation team operating in Egypt.

Let us now consider the problems of deeper research. The situation looks opposite than when the surface is concerned, at least as for as resistivity is concerned. In fact, sandstone is more resistant than the clay above, and the crystalline rocks are much more resistant than sandstone. In this case if the sandstone's thickness is the same, or lower, than that of the clay, the three-strata curve coincides almost perfectly with a two-strata one and the identification of the average-resistant formation is impossible.

Moreover, considering the fact that, on top of the clay, there is another resistant formation, it is easily understood how things grow considerably worse. One may infer, therefore, that the electrical method may be useful, in such cases, only when there are very thick formations covered by very thin ones.

Unfortunately, it often happens that the intermediate formations are not very thick, and therefore the electrical soundings are absolutely powerless. This is especially true in cases such as Isna's, where the intermediate formation's resistivity - that is, the nubian sandstone's - is not much higher than the clay's; both because the sandstones are alternated with clay, and because the water they are imbued with is salty enough.

In order to overcome this difficulty, one may resort to refraction seismis or to combined refraction and reflection, because the elastic modulus contrast between the sandstone and the clay above is quite sharp. Furthermore, seismic methods have a much higher selective power than electric ones.

Electrical soundings have revealed a bed formation definitely resistive which, evidently, was to be credited to the base crystalline formation from the start, on account of its high resistivity. It was impossible to establish whether or not there was an intermediate formation. A drilling met 200-m-thick Nubian sandstone, leaning on the crystalline, at 260 m depth.

The ratio between the thickness of the sandstone and clay formations is slightly lower than 1, therefore this is the case where a correct intepretation is impossible. A very careful examination of the electric soundings, however, has permitted to remark the presence of sandstone in a few zones and to calculate their depth, though with some uncertainty. Generally, however, in spite of all efforts, interpretation is actually impossible.

So far, we have only mentioned difficulties; we must say, however

that, aside from the problem of sandstone location, electrical prospecting in zone of Isna was very successful, since it was possible to trace a very detailed map of the level lines of the impermeable formation's top (fig. 2), and also, is its broad outlines, the crystalline top.

The soundings were distributed rather evenly, with an average density barely superior to 1 per km^2; only 46 of them have a 4 km length, and this the reason why the bed itself could only be followed in its outline. All other soundings - more than one hundred - have total spreads lower than 1 km.

Electronic-voltmeter measuring instruments were very helpful, because of their high sensivity, which allows acceptable results even with currents, of their high input impedance, which makes measurements possible even with very high contact resistances of the electrodes; and, finally, for the quickness and exactness of their measurements.

4 - Hydrological Surveys

Drillings - Mechanical drillings with a hydrological goal were carried out with a sufficiently wide diameter (10" and 12") in order to accomplish the regular pumping tests with submerged pumps. Drillings with a much lower diameter (2" and 4") were carried out for the purpose of piezometric controls of the water-table. Usually the percussion system was applied for loose formations and depths up to 60-70 m; the rotary system had to be resorted to for greater depths and stone formations.

Phreatimetric strata surveys and measurements of the Nile river levels-

Through periodic phreatic stratum controls, it was possible to obtain very interesting datas regarding the movement of the water-table of Isna and Samalut, as well as on the reloading features of the Nile river downflows and of the absorption of irriguous waters taking place in already cultivated areas.

A regulation weir at Isna on the Nile river modifies remarkably the downflows at the heights of the river, up and downstream of the weir, with the evident consequences on the regime of the water-table stratum. In the diagram at fig. 3, the two phenomena of flood and the two ones about low water are clarly shown.

In the Isna district, the water-table oscillations are characterized , however, by a trend parallel to that of the river, with a delay going from two to four months. Through the whole series of phreatimetric stratum surveys, in these cases, it is possible to achieve a set of indicative notions with regard to the behaviour of the water-table stratum, as far as its filling again and downflows toward the Nile river.

In the Isna district, water-table oscillations appear extremely low when compared with the levels of the Nile. In order to understand such a phenomena, which is certainly common to all other water-tables strata in the same conditions in the Nile river valley, it is very interesting to know what was ascertained in this district through the hydrological controls that were carried out. Where, when ground-water stratum is in the exhaustion phase, the Nile river flood takes place (in the trimester of August - September - October), with the consequent filling again from the left bank of the river of seepage

water; at the same time, the basin-and-canal irrigation in the cultivated land begins to work fully. The exhaustion of the ground-water stratum, in such conditions, is thus checked by the irrigation; indeed, a new rise phase begins, more or less at the time when the Nile river flood is beginning to exhaust (November). Therefore, it must be assumed that the aquifer receives no real supplies of seepage water from the Nile; rather, the vadose water percolation, deriving from the irrigation, have a sizeable influence on the filling again of the aquifer stratum. Later, as the water-table stratum trends to its highest level, the Nile river levels reach a minimum peak (December), followed by a new flood which reaches its maximum in February; in the aquifer stratum instead, an exhaustion cycle is taking place. This, however, is remarkably checked by the irrigation of the months from April to August, which is uninterrupted throughout such a long period of time. Consequently, when the irrigation is farily advanced, the water-table stratum touches a new maximum. The limited size phreatimetric oscillations, when compared to the Nile's, gives the impression of a practically stable equilibrium; this impression is due to the complicated action of the various influences caused by the filling again of the Nile and by those deriving from vadose irriguous absorption waters.

Piezometric quotas of the deep aquifer stratum -

In the well WA 4 C the first waters in pressure of the Nubian series was found at about 200 from the ground surface (g.s.) (-100 m below sea level); in the well IS 2 A/B/ the Nubian series waters were found in the section at 350-450 m below the ground surface; at 465 m below sea level the crystalline substratum in the form of diorite was found. The well WA 5 B at a depth of 500 m g.s. appeared still sterile from an hydrological point of view. The artesian waters found at Wadi Abbadi showed temperatures of 29° c, those found at Isna 39° C and levelled at 104 m above sea level.

Capacity of the wells and comparison with the techniques adopted in drilling -

Pumping tests proofs and tracings of characteristic curves fro each research well, were meant to ascertain not only the real output of the wells, but also the efficiency of the various methods experimented in the drilling and of the covering adopted.

It is interesting to point out how, for example, four months after the end of the preceding pumping test, the well IS 4 A deceased considerably its average specific capacity down thus showing the partial occlusion of the filtering part of the covering columns, made of metal pipes of a Ø 10"1/2 diametre, fissured and lined with a close brass net (Reps). From several comparisons of this kind, the conclusion was drawn that the best outputs of the wells are consequential to the drilling diametre, a convenient draining around the filtering walls of the tubings, and, finally, to the kind of filter used. In medium grain sands, which are often the medium of the aquifer in the Nile river valley, the special anti-sand filter with bridge elements (Slotted Bridgetype) is more suitable than Reps nets. Also in deep wells, dug in Nubian sandstone, the remarkable decrease of hydrological output caused by betonite muds during the drilling was noticed.

Permeability tests-

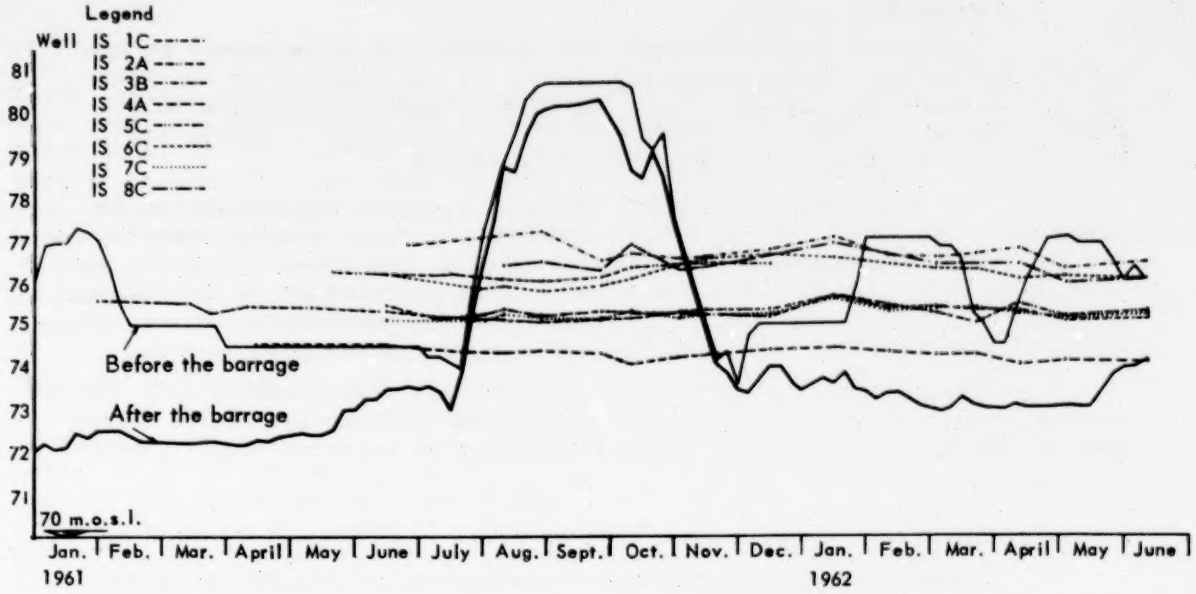
Completing capacity tests, the permeability measurements of the aquifer have given elements extremely useful in the planning of the wells and of the operating capacity to be allotted to each of them. The well-known formulas of DUPUIT and THIEM have given , majority of cases, not very reliable results, much lower than real values.

The most dependable results derived from the application of the procedure proposed by PUPPINI, with regard to permeable complex constituted generally of hetherogeneous elements. For each of these tests, special spy-pipes have been placed around a main well fully penetrating in the aquifer. By means of these pipes, a few level curves of the depression cone, ground the well corresponding to a definite regime output, have been traced.

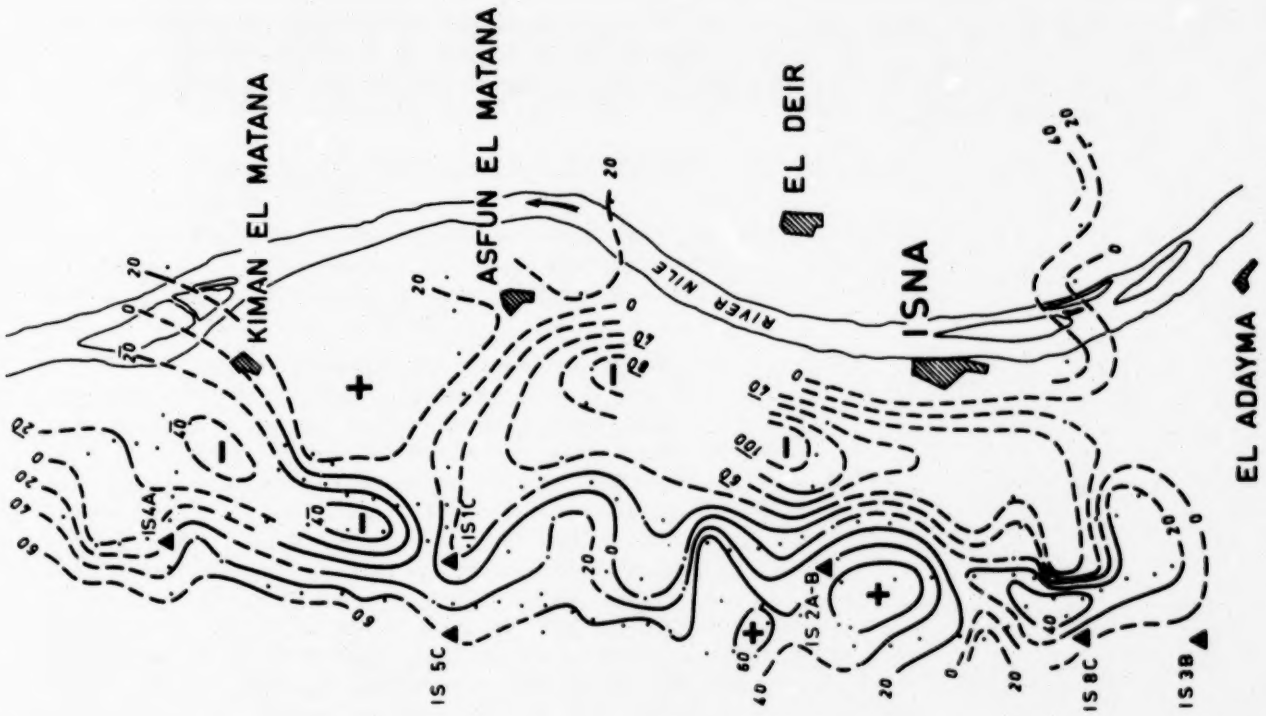
In the Isna district, the permeabilities thus measured have reached average values of 0.20 - 0.25 cm per second. The aquifer discovered in the Samalut district has shown an average permeability value of about 0.10 cm per second.

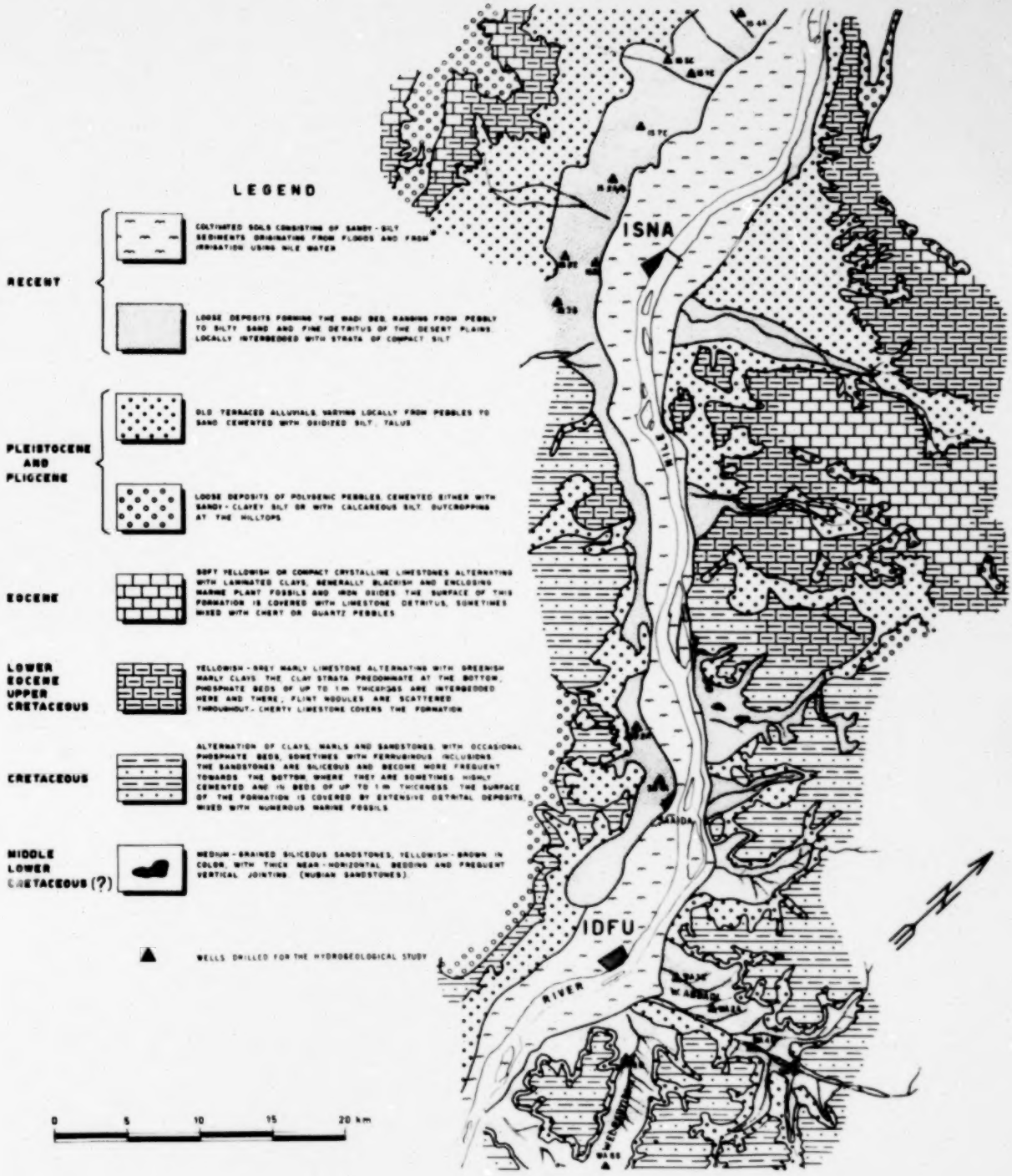
Quality of the waters -

Detailed chemical analyse were being carried out during pumping-tests, with results of interest with regard to the influence of the soils on the quality of ground waters. Where the aquifer stratum appeared thick as, for instance, in most of the Isna district, the salt residua ranged from 0.25 to 0.50 g per 1 (Whole the Nile river water has a salt remanent of 0.10 g. per 1.). On the other hand, in areas with little presence of phreatic water strata these reached residues of the range of 1.25 - 1.50 g. per 1., with very high Cl and SO_4 concentrations, deriving from the salt melted in the soils crossed by vadose waters. The ground-water of the nubian sandstone stratum showed all over very high salt residues, up to 2.30 g. per 1., in most part constituted of chlorides, sulphates and ferrous oxides.



Nile's levels oscillations at the Isna Barrage during the years 1961, 1962




LEGEND
RECENT
CULTIVATED SOILS CONSISTING OF SANDY - SILT SEDIMENTS ORIGINATING FROM FLOODS AND FROM IRRIGATION USING NILE WATER
LOOSE DEPOSITS FORMING THE WADI BED, RANGING FROM PEBBLY TO SILTY SAND AND FINE DETRITUS OF THE DESERT PLAINS, LOCALLY INTERBEDDED WITH STRATA OF COMPACT SILT
PLEISTOCENE AND PLIOCENE
OLD TERRACED ALLUVIALS, VARYING LOCALLY FROM PEBBLES TO SAND CEMENTED WITH OXIDIZED SILT, TALUS
LOOSE DEPOSITS OF POLYGENIC PEBBLES CEMENTED EITHER WITH SANDY - CLAYEY SILT OR WITH CALCAREOUS SILT, OUTCROPPING AT THE HILLTOPS
EOCENE
SOFT YELLOWISH OR COMPACT CRYSTALLINE LIMESTONES ALTERNATING WITH LAMINATED CLAYS, GENERALLY BLACKISH AND ENCLOSING MARINE PLANT FOSSILS AND IRON OXIDES. THE SURFACE OF THIS FORMATION IS COVERED WITH LIMESTONE DETRITUS, SOMETIMES MIXED WITH CHERT OR QUARTZ PEBBLES
LOWER EOCENE UPPER CRETACEOUS
YELLOWISH - GREY MARLY LIMESTONE ALTERNATING WITH GREENISH MARLY CLAYS. THE CLAY STRATA PREDOMINATE AT THE BOTTOM. PHOSPHATE BEDS OF UP TO 1 m THICKNESS ARE INTERBEDDED HERE AND THERE, FLINT NODULES ARE SCATTERED THROUGHOUT. CHERTY LIMESTONE COVERS THE FORMATION
CRETACEOUS
ALTERNATION OF CLAYS, MARLS AND SANDSTONES WITH OCCASIONAL PHOSPHATE BEDS, SOMETIMES WITH FERRUGINOUS INCLUSIONS. THE SANDSTONES ARE SILICEOUS AND BECOME MORE FREQUENT TOWARDS THE BOTTOM WHERE THEY ARE SOMETIMES HIGHLY CEMENTED AND IN BEDS OF UP TO 1 m THICKNESS. THE SURFACE OF THE FORMATION IS COVERED BY EXTENSIVE DETRITAL DEPOSITS MIXED WITH NUMEROUS MARINE FOSSILS
MIDDLE LOWER CRETACEOUS (?)
MEDIUM - GRAINED SILICEOUS SANDSTONES, YELLOWISH - BROWN IN COLOR, WITH THICK MEAN - HORIZONTAL BEDDING AND FREQUENT VERTICAL JOINTING. (NUBIAN SANDSTONES)
WELLS DRILLED FOR THE HYDROGEOLOGICAL STUDY
ISNA
IDFU
NILE
RIVER
0 5 10 15 20 km

GEOLOGICAL MAP

OF THE NILE VALLEY BETWEEN WADI ABBADI AND ISNA

1650 E - Nov. 1962 - 1,600